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7. Author(s) (i) DR. JAAFAR BIN AHMAD
(ii) SHU YEOH KHOON

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16. Abstract

The main objective of the Geological Survey of Malaysia LANDSAT Follow-up Program is to conduct, by using inexpensive and unsophisticated visual techniques, analysis of LANDSAT MSS imagery for the identification of circular features, major fault traces, fold structures, rock units and raised beaches. These information were applied to on-going projects on the ground where the association between structures and mineralization, the distribution of heavy minerals among the raised beaches and the delineation of a flood plain for groundwater investigation were considered.

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GEOLOGICAL AND HYDROGEOLOGICAL INVESTIGATIONS IN WEST MALAYSIA

Investigation No. 29830

Dr. Jaafar bin Ahmad
Mr. Shu Yeoh Khoon

Geological Survey,
Malaysia.

June, 1977

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1.0 Introduction

Since the middle of 1971 the Geological Survey of Malaysia had initiated a program to acquire and use LANDSAT data for geological investigation. However, it was only in May, 1975 that the Survey was accepted as a participant in NASA'S LANDSAT Follow-up Program.

The main objective of this program is to conduct a structural analysis of Peninsular Malaysia on a regional scale by use of LANDSAT imagery, and to apply the results of this analysis to on going projects on the ground.

The program lasted 10 months and within the period of April to June, 1976, three batches of LANDSAT-2 data products were received. Of these only three scenes covering the east coast of the peninsula are suitable for analysis.

This report is restricted to work covering only the east coast where the structural analysis is compared to known geological units and structures, and mineral distribution. Investigations into heavy mineral distribution among the raised beaches are also considered. Delineation of the flood plain of the Trengganu River is also attempted to help in the groundwater investigation there.

2.0 Objectives

The objectives of this study can be expressed briefly as follows:-

(i) Geological structures will be analyzed on a regional scale by using black and white and colour composite imagery. Structural geologic maps will be produced or improved.

(ii) Data from LANDSAT-2 imagery will be used with airbone geophysical data to explore for base metal along the central belt of the Malay Peninsula.

(iii) Ground-water resources will be evaluated by LANDSAT imagery and serve as a guide to a West German hydrological mission operating in Peninsular Malaysia from 1974 - 1977.

Figure 1. Landsat - 2 Coverage

Scale 70 Miles to an Inch

Miles 50 0 50 100 Miles

1/2 - LANDSAT IMAGERY WITH REFERENCE NUMBER

(iv) Off shore currents, ancient shorelines, and the distribution pattern of raised beaches along the east coast of Peninsular Malaysia will be studied by LANDSAT imagery. The heavy mineral contents of these beach deposits are currently being systematically investigated by drilling.

Due to the very restricted nature of the coverage by LANDSAT-2 only part of objectives (i), (iii) and (iv) could be fulfilled while objective (ii) could not be considered because of the non-existence of imagery coverage of the central belt area.

3.0 Products Received and Analysis

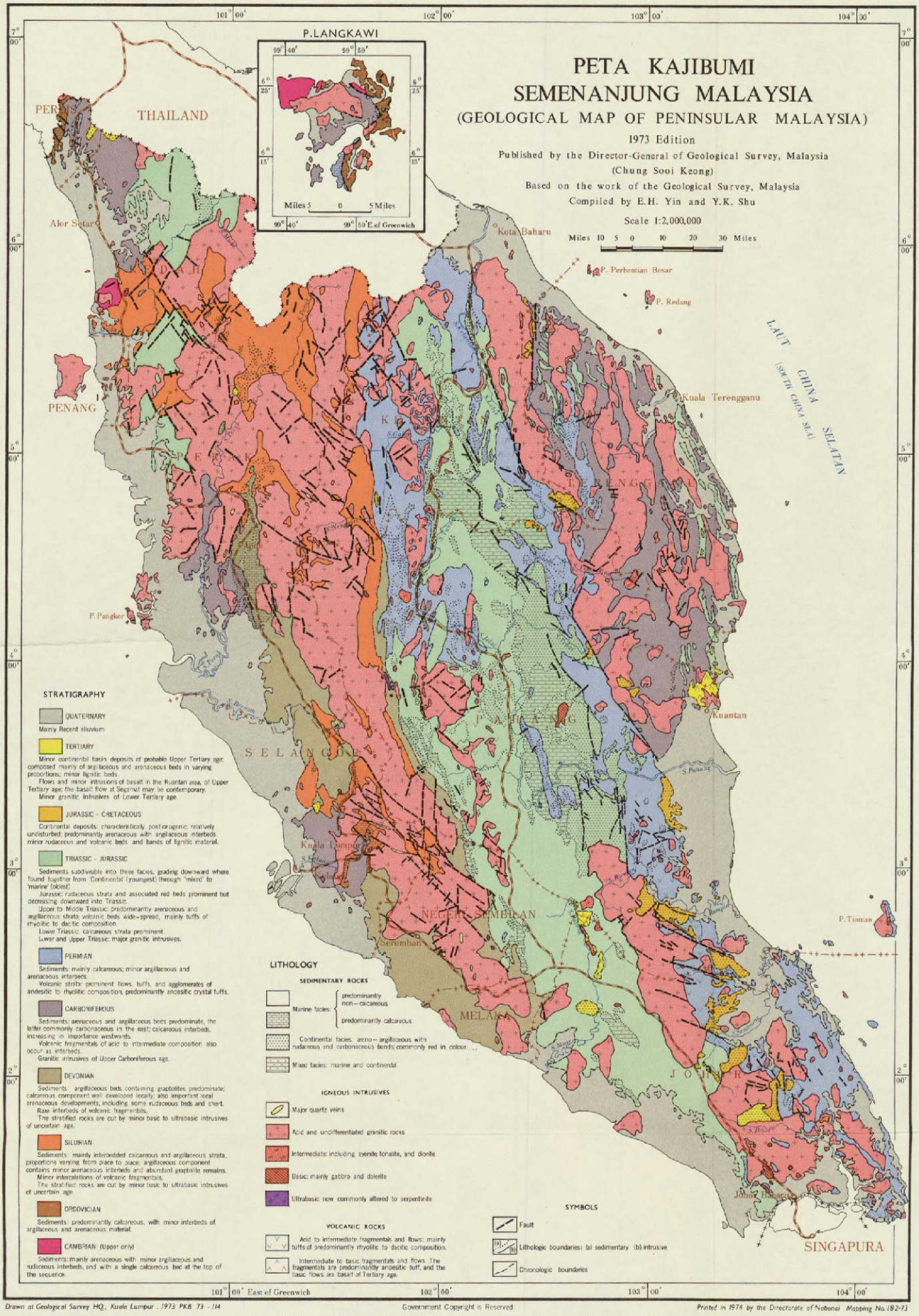
Within the period covering the months of April, May and June, 1976 three batches of LANDSAT-2 data products were received. Till the end of the program period no new data was received.

In all 9 sets of imagery covering 8 scenes were received (Fig. 1). Each set of imageryconsists of 9 x 9 inches black & white positive print and 2.2 x 2.2 inches positive transparency of bands 4, 5, 6 and 7. Subsequently orders were placed for 14.6 x 14.6 inches black & white positive print of bands 5 and 7.

The following are details of the MSS products received:-

Fig. 1 Scene No.	Photo ID No.	Date received	Area	Products
1/2	2433 - 02524	4.6.76	Hatyai, Southern Thailand	MSS band 4, 5, 6 & 7, 9" x 9" positive print, 2.2" x 2.2" positive transparency 14.6" x 14.6" positive print, band 5, 7.
1/3	2433 - 02531	4.6.76	Langkawi Island Malaysia.	"
2/2	2432 - 02470	17.6.76	Pattani, Southern Thailand	"
4/2	2430 - 02360 2448 - 02353	17.6.76 17.6.76	Northeast Trengganu Malaysia	"
4/3	2448 - 02355	17.6.76	Southern Trengganu Malaysia	"
4/4	2448 - 02362	17.6.76	Southeast Pahang Malaysia	"
5/1	2411 - 02312	23.4.76	South China Sea	MSS band 4, 5, 6 & 7, 9" x 9" possitive print, 2.2" x 2.2" possitive transparency
5/2	2411 - 02314	23.4.76	Tioman Island Malaysia	

FIGURE 2



Drawn at Geological Survey HQ., Kuala Lumpur. 1973 PKB 73 - 114

Printed in 1974 by the Directorate of National Mapping No. 182-73

Enquiries on the geological aspects of this map should be addressed to the Director-General of Geological Survey, P.O. Box 1015, Ipoh, Peninsular Malaysia.

3.1 First Look Evaluation

Scene No. 1/2 : This is an excellent imagery with less than 10% cloud cover of the Hatyai area of Southern Thailand. Only a small portion of Northern Perlis State of Malaysia is included. Because the area is outside Malaysia the imagery commands the lowest priority for evaluation.

Scene No. 1/3 : This is a good imagery of the Langkawi Islands of Malaysia. The geology is complex and of mainly lower Palaeozoic rocks. It is unfortunate that only the islands are covered which are of limited areal extend and subsequently large scale features are absent.

Scene No. 2/2 : This is another excellent imagery with less than 10% cloud cover of the Pattani area of Southern Thailand. Since there is no Malaysian territory involved the imagery will not be evaluated.

Scene No. 4/2 : This scene was covered twice, once in 27.3.76 and another in 14.4.76. In the earlier take high cloud cover obscure most of the land features while the following one is almost cloud free and is excellent for geologic interpretation. The scene covers a small portion of Northeastern Trengganu State around the state capital, Kuala Trengganu, and the Redang Island offshore.

Scene No. 4/3 : This scene covers most of southern Trengganu State and a small portion of Pahang State. Cloud cover is about 15% but resolution over most of Trengganu is good. Band 6 and 7 are excellent for geologic interpretation.

Scene No. 4/4 : This scene covers the whole of southeast Pahang State, the location of the largest and most ambitious land development scheme. With 40% cloud cover, only part of the geology is seen. It is also possible to delineate the coastal belt where the raised beaches are located. Some of the larger faults are discernible.

Scene No. 5/1 : This scene is entirely in the South China Sea.

Scene No. 5/2 : This scene covers the northeast coastline of the Johor State including the Tioman Island offshore. Unfortunately the land area has very high cloud cover, up to 70%. As such the imagery is unsuitable for interpretation.

With the ending of our standing request as agreed in the program, only three (3) imagery covering the east coast of Peninsular Malaysia fit into part of our requirements for the LANDSAT Follow-up Program. These three imagery cover the states of Trengganu and Pahang with Photo ID Nos. 2430 - 02360, 2448 - 02353 and 2448 - 02355 taken on 14th April, 1976.

3.2 Technique

The imagery product, used for interpretation are MSS band 4, 5, 6 & 7 in the form of 9 x 9 inches black and white prints and 70 mm. positive transparencies, and 14.6 x 14.6 inches black and white print for band 5 and 7.

These imagery were analysed by simple aerial photo interpretation techniques which include stereoscope, zoom microscope and ronchi grating. A 4-band additive viewer was purchased to produce false colour composite, but unfortunately this equipment was not delivered in time for this program. Similarly a zoom transfer scope cannot be delivered in time also.

The interpretation for each scene was done on band 6 and 7 since they show better overall contrast for geologic features. Band 5 was employed for supplementary information and greater accuracy of features such as roads, land-use pattern and beach deposits. The information were transferred to a number of transparent overlays of Kodatrace, each for specific features. The information from each overlay were finally transferred to a single transparency which shows a composite of all the features picked up from the imagery.

In the interpretation the following features were noted:-

(i) geological units (to distinguish each unit and see mutual relationship);

(ii) geological structures
bedding, foliation, fold, circular structure and lineation (fault);

(iii) topographic features
coast line, river, town, and beach lines.

The composite interpretation map was compared with existing geological maps and field information. The presence of any significant feature was used to upgrade geological maps and to improve our existing geological knowledge of the country.

3.3 Scene Description

The three scenes cover an area stretching from the northeastern tip of the Trengganu State coastline southwards through the central and southern Trengganu State and into southeastern Pahang State. The northern portion is completely cloud free but cloud cover increases rather rapidly southwards which obliterates most of the ground details (see Fig. 3).

The area covers almost the entire eastern granite belt (Eastern Belt) of Peninsular Malaysia of Upper Permian and Upper Triassic age. The granite intrudes sedimentary units of mainly aegillaceous and arenaceous rocks of Carboniferous age. There are also indications of younger units of arenaceous and rudaceous rocks which exist as narrow, tightly folded belts.

Towards the western edge of the imagery is a broad zone of sediments which are characterized by its well developed folds trending north-northwest. They comprise thick sequences of argillaceous, arenaceous and rudaceous rocks of probably continental origin, ranging in age from Jurassic to Cretaceous. These broadly folded Mesozoic rocks form the eastern edge of the Central Belt of Peninsular Malaysia which is mainly of Permian to Upper Mesozoic age. The boundary between the Central and Eastern Belt appears to be partly faulted or tectonic in origin and it trends north-northwest.

PLATE I : Image of South Trengganu and East Pahang State, MSS Band 5 showing cultural features.

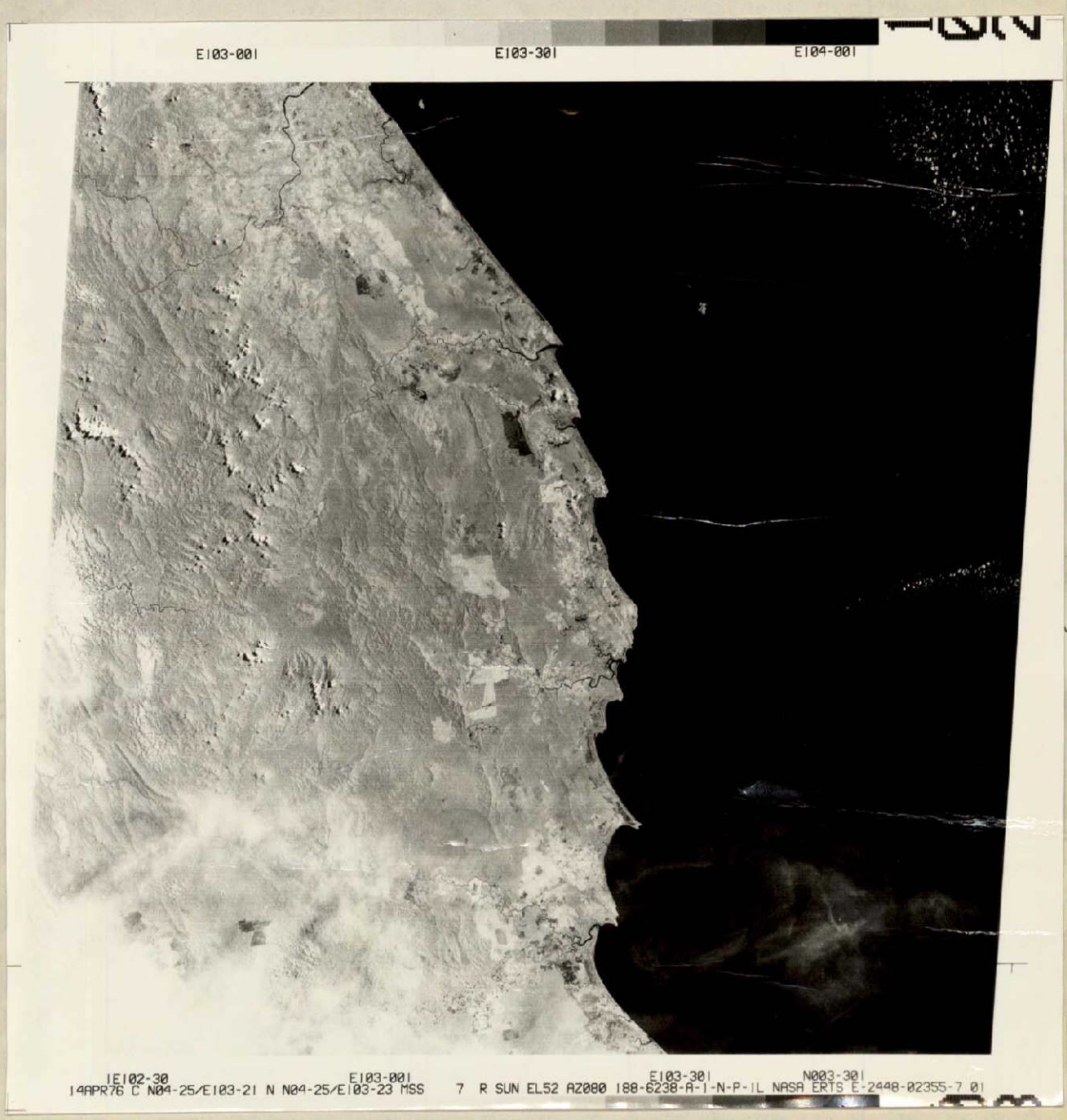


PLATE II : Image of South Trengganu and East Pahang State, MSS Band 7 showing structural features as depicted in Figure 3.

The dominant northerly to north-northwesterly tectonic trend of the area is evident by the orientation of the igneous bodies and sedimentary units. This trend appears to have persisted from Carboniferous to Mesozoic.

3.4 Evaluation

Considering the upper half of the interpretation map, it can be noted that the general outlines of the major igneous bodies were delineated. Apart from minor details and indeterminable features, these outlines tie up fairly well with the latest geological map (Fig. 2).

The Younger Sediments which is probably Mesozoic in age is physiographically distinct as they invariably stand out as narrow, elongated (> 10 miles) ridges. The contrast is further enhanced by their location in coastal flats and within the Older Sediments which normally form low rolling hills. Lithologically the Younger Sediments are distinct in that they are essentially arenaceous to rudaceous with red sandstones and conglomerates.

To the west the Younger Sediments, which are dated as Upper Mesozoic in age, are broadly folded with prominent fold axes of up to 17 miles in length. They represent the eastern edge of the Central Belt of Peninsular Malaysia. Red shales, sandstones and conglomerates are also present. A mildly folded to flat-lying equivalent of the same sequence occur on the Gagau plateau near the headwater of the Trengganu River. Similar rock units are found scattered along the eastern boundary of the Central Belt south to the state of Pahang. However, most of these units are not evident in the imagery. The boundary between the Central Belt and the Eastern Belt is partly intrusive (with granite) and faulted (with the Older Sediments). A program for a uranium survey and phosphate exploration is being considered for the Younger Sediments in the Central Belt.

The Older Sediments are of Lower Carboniferous to Permian age. They consist mainly of shale and sandstone with subordinate tuff and phyllite. Folding is tight and complex, except for a long narrow belt of folded Permian rocks at the upper reaches of the Trengganu River where a regional fold axis appears to be evident. These sediments are intruded by the igneous bodies (mainly granite)

giving rise to extensive mineralization along a broad zone stretching south from Bukit Besi, on the upper reaches of the Dungun River, to the Bandi area, at the headwater of the Chukai River. It is interesting to note that this region has the highest density of fractures and circular structures which might represent minor intrusive bodies related to the mineralization. Iron and tin were mined at Bukit Besi while tin, iron, wolframite and silver occur in Bandi. Most of the intrusive bodies, related to the circular structures, are probably different phases of granitic intrusion. Only two of these structures have been identified as non granitic in composition. They are the diorite bodies at Kelip Hill near the headwater of Dungun River and at Mount Besar, 15 miles to the southwest. Both bodies intrude only the Older Sediments.

To the south, about 10 miles north of the headwater of the Kuantan River, is a circular structure which appear to have the features of an impact structure. There are no accurate ground information available. The structure is about circular in outline and 2 miles across. The eastern half of the rim consists of a steep, narrow ridge rising to 2,000 feet in elevation. The ridge is underlain by sedimentaries. The western rim is less well defined and is underlain by granitic rocks.

The fracture systems trend northwest and northeast to east-northeast. This is quite in keeping with the known trend of the major fracture systems of Peninsular Malaysia. However, the imagery show a higher density of northeast to east-northeast fractures than identified by past mapping. The northeast fracture system is an important feature of the geology of the Trengganu State as it is invariably intruded by a system of dykes (ranging from a few inches to 50 feet) with varying composition of diorite, dolerite and lamprophyre. The fractures also indicate some of the granite/sedimentary contacts are faulted.

The imagery covering the area south of the Pahang River (southeast Pahang State) has a high percentage cloud cover and poor resolution. Only a very general outline of the granite plution and the major fault traces could be delineated. The only features of interest are the intrusive structures (circular) of dolerite bodies which are associated with iron mineralization around Bukit Ibam, 15 miles south of the Pahang River. Bukit Ibam was the largest iron ore mine in Peninsular Malaysia.

As shown in the interpretation map the coastal swamps and Quaternary deposits were delimited for the entire east coast. Strips

of raised beaches containing sand ridges and intervening swamps can also be demarcated. Field investigations are being undertaken to assess the potential of silica sand in the raised beaches along the Trengganu State coast. Investigations into the groundwater potential of the Quaternary sediments around Kuala Trengganu and Tajong Gelang, 12 miles north of Kuantan are being undertaken.

4.0 Accomplishments

The results as detailed in para 3.0 were compared and applied to past as well as on-going projects. Depending on application, some investigations have found the LANDSAT data to be helpful while others are less indicative.

4.1 Geological Structure and Mineralization

By comparing Figure 3 and Figure 4 it is quite apparent that only the general outlines of the granitic intrusives could be delineated by the LANDSAT imagery. With low relief, especially areas adjacent to the coast, the individual geological units are less well defined.

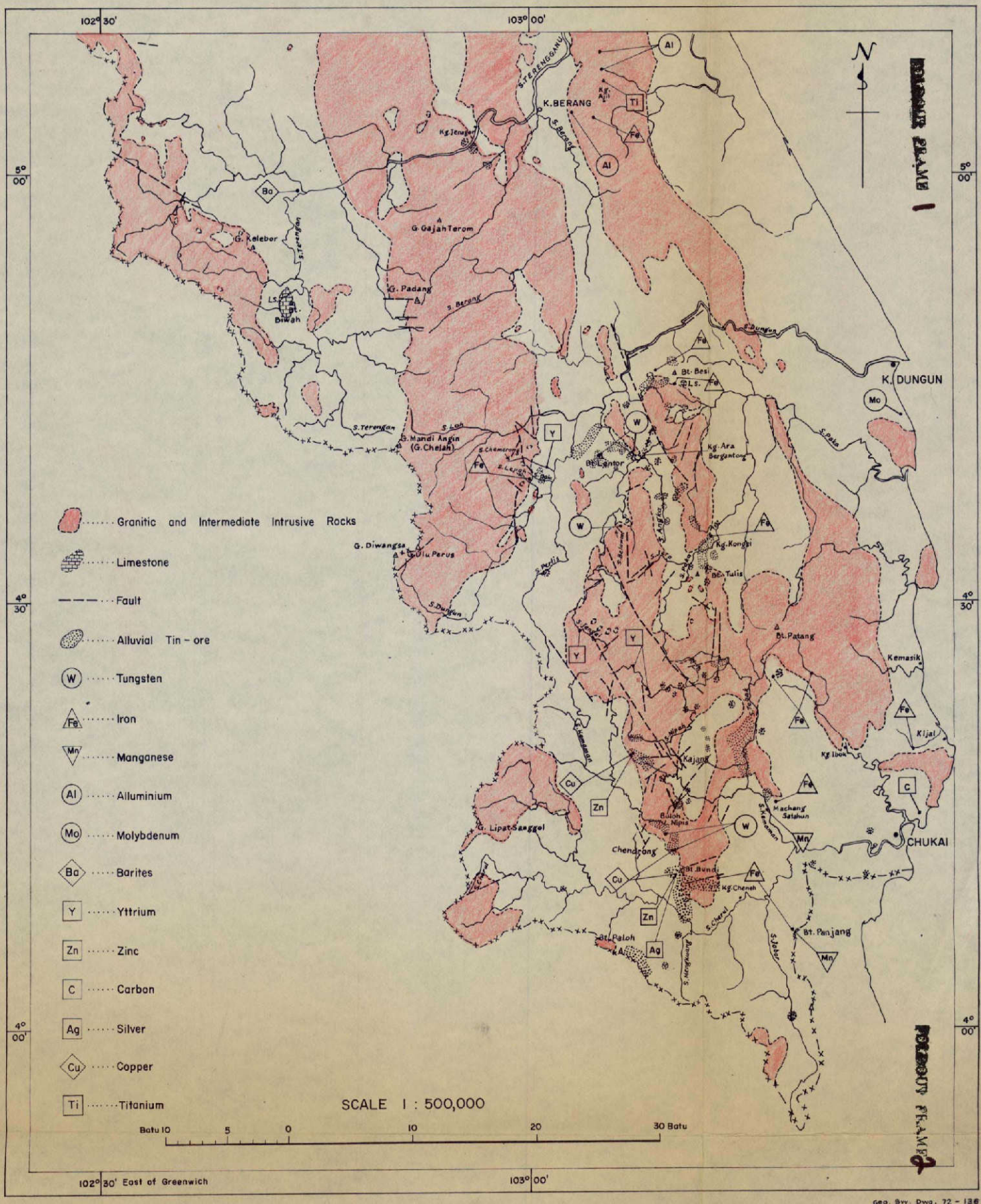
Large geological structures are easily discernible in the imagery, especially the circular structures which are in most cases intrusive in nature. Faulting along the northeastern direction has never been mapped on a large scale in the past although most of the dykes are found following the same trend.

The circular structures, identifiable only on the imagery, were found to be closely associated with widespread mineralization along the north-south trending Bt. Besi, Bt. Tulis and Bt. Bundi tin-tungsten-iron metallogenic belt. Smaller concentrations of circular structures at the headwaters of the Trengganu River and the Tekai River, across the border in the Pahang State, suggest the possibility of as yet unproven mineralized areas for future exploration.

In the Bt. Besi - Bt. Bundi tin-tungsten-iron belt the mineralization is associated with granitic intrusives. Several fracture zones are present which are occupied by late phase acid igneous rocks, greisen zones and quartz-tourmaline veins. These veins usually trend northwest through north to northeast.

FIGURE 4

Mineral Distribution Map of the Trengganu Tengah Area



Mineralization is normally restricted to areas around granite/sediment contact, adjacent to satellite stocks of granitic rocks and sedimentary areas underlain by a shallow-lying granitic body.

The so-called impact structure or crater as interpreted from the imagery was investigated by a literature survey of work done in the area in the past and a limited amount of fieldwork undertaken south of Bt. Paloh (Fig. 5). The Bt. Paloh ridge is a razor-sharp ridge forming a semicircular outline which is the most prominent half of the structure. This ridge is underlain by hornfels and spotted slate in contact with granite lower down the inner flank of the ridge.

The circular structure which is about 2 miles wide occupies the northeastern end of a 6 miles long elongated granite body which is quite heavily mineralized with tin. This conclusion is amply supported by the abandoned tin mines located along the alluvial flats of the Reman River and the Bakah River.

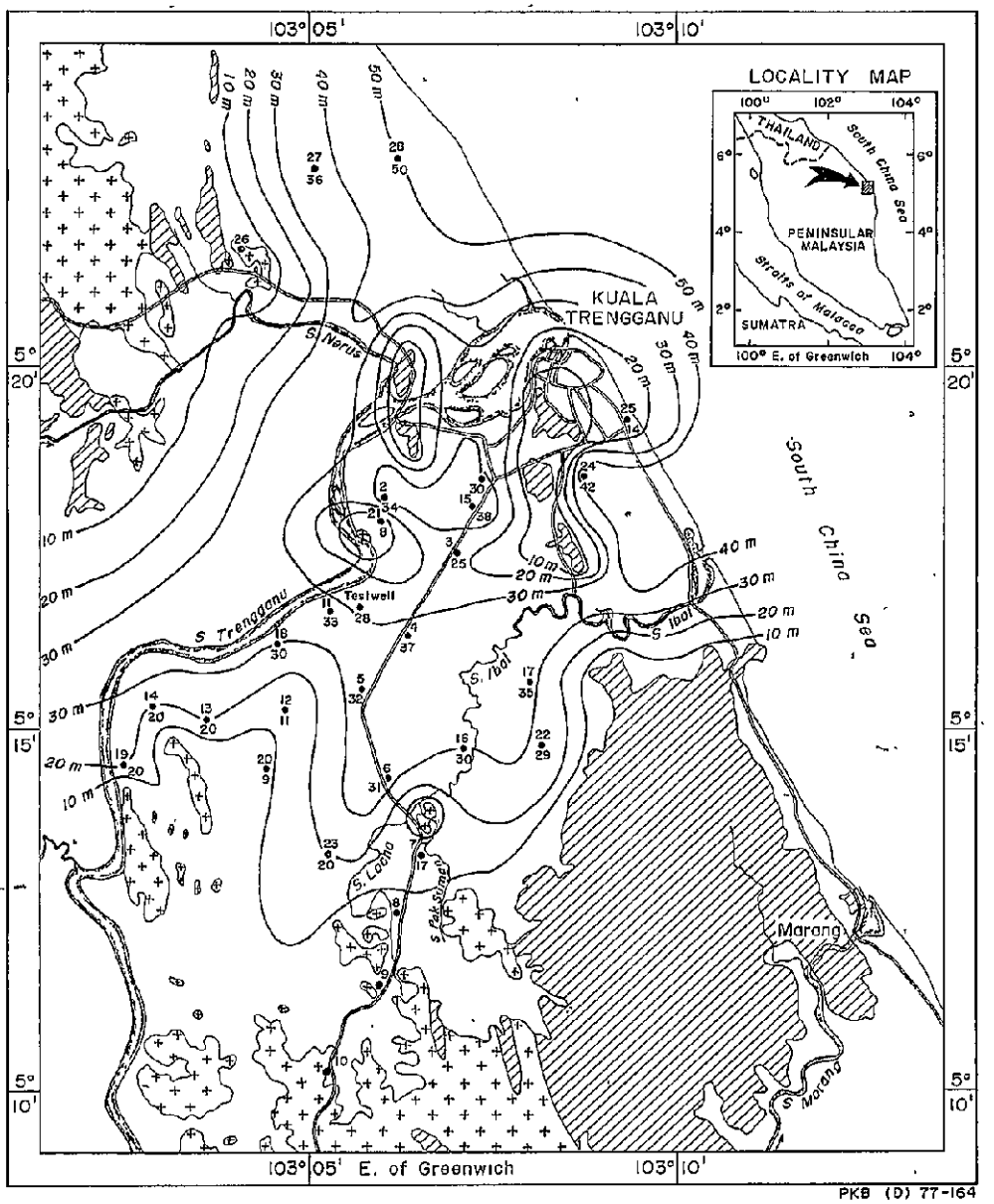
Due to the deeply weathered nature of the bedrock the field condition is unsuitable for investigation into the possibility of the existence of an impact structure. However, due to the fact that the structure forms part of a granitic body, the consensus of opinion is that this structure is likely to be the surface expression of a granitic stock.

4.2 Ground-water Resources

One of the expressed objectives was to utilise LANDSAT imagery for a German-Malaysian hydrogeological investigation program covering the period 1974 to 1977. This program has a number of projects scattered throughout the Peninsula, but the only one that falls within the coverage of the imagery is at Kuala Trengganu, the capital of the state of Trengganu (Fig. 1). This is rather unfortunate because the largest project which centred around Kota Bharu 90 miles to the northwest, falls outside the imagery.

The Kuala Trengganu delta which is drained principally by the Trengganu River is small by comparison, with a length of about 16 miles and a width of 7 miles. Due to its limited areal extent it was found that even at a scale of 1:½ million it was difficult to outline the delta on the imagery. No significantly large old river course could be discerned nor any sign of recent faulting preserved.

FIGURE 6. KUALA TRENGGANU
Thickness of the Quaternary Sediments



SCALE

Mile 1 0 1 2 3 Miles
Kilometre 1 0 1 2 3 4 Kilometres

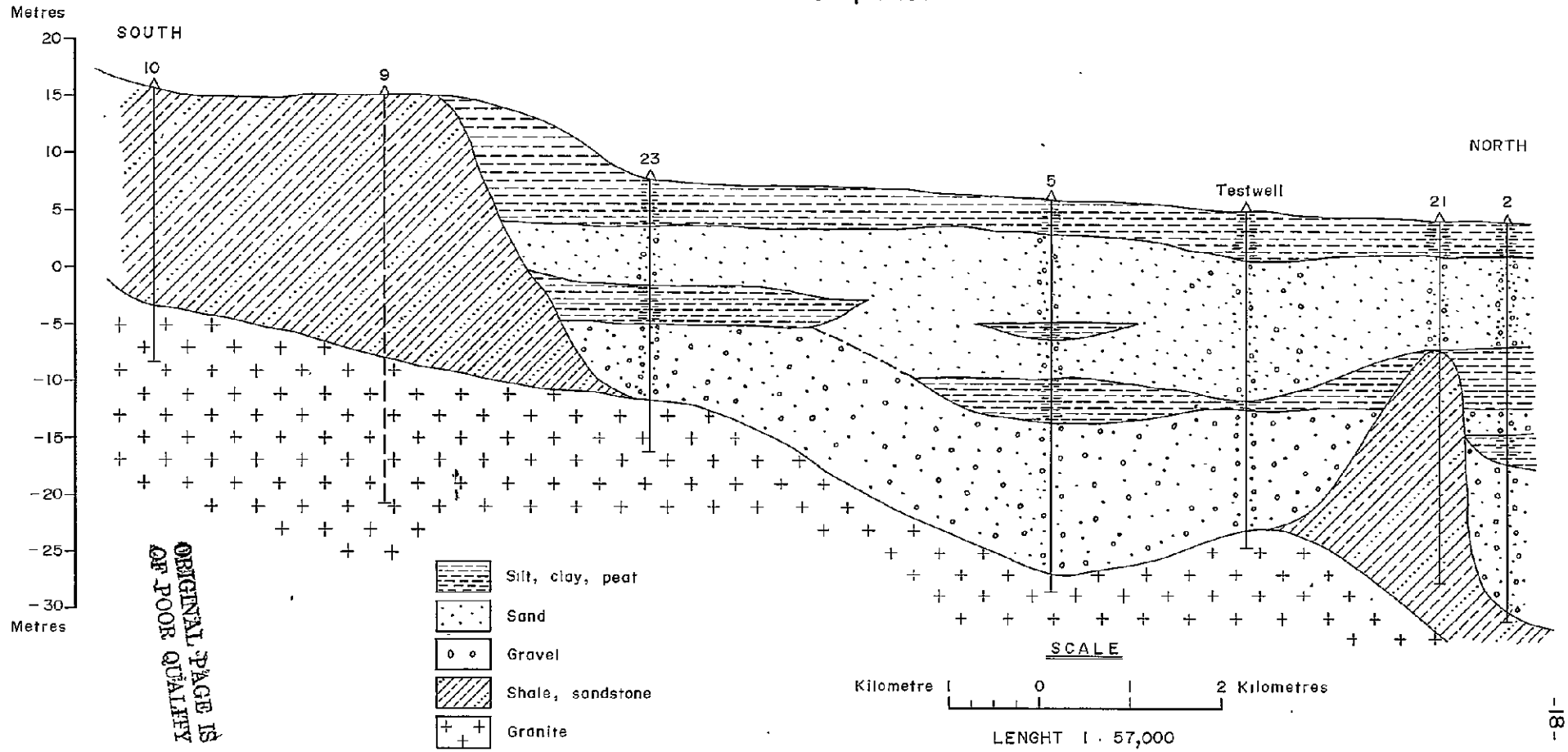
LEGEND

22 Number
• Borehole
29 Thickness of Quaternary Sediments

Granite
Arenaceous
} Outcropping bedrocks

20 m — Contour lines thickness of Quaternary Sediments

FIGURE 7. KUALA TRENGGANU
Geologic Cross Section
Simplified



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The area is covered almost entirely by unconsolidated Quaternary alluvium which is underlain by areno-argillaceous bedrock of Carboniferous age. Further inland to the west the bedrock is granitic (Fig. 6).

A number of exploratory boreholes were effected north and south of the Trengganu River where groundwater is needed to supplement the water supply to the State capital. The Quaternary sediment consisting of clay, silt, sand and gravel interbeds has thickness ranging from a few metres to 50 metres.

In general, two main aquifers were delineated north of the River while only one thick aquifer with lenses of impervious silt-clay layers exists to the south (Fig. 7). Both aquifers are composed of sand and gravel and have surface recharge capability. A pumping test established a constant yield rate of ½ million gallons/day for one well and the water quality is suitable for human consumption.

The Pahang River has a much larger delta 150 miles to the south (Fig. 3). However, no investigation has ever been carried out in this area due to the absence of large urban and industrial centres.

4.3 Beach Sand Investigation

In view of the wide distribution of beach ridges along the east coast of the Peninsula a field survey into the heavy mineral content of these ridges were initiated.

The imagery were used to delineate the broad distribution pattern of the ridges which are quite distinct from the rest of the land features. Old beach lines are also pronounced in areas north of Kuala Trengganu and between Kuantan and Pdg. Endau to the south.

Due to the total absence of suspended sediment in the South China Sea, off shore current pattern could not be elucidated. However, by noting a very limited number of sand bars, the general direction of the longshore drift appears to be northwestery along the coast north of Kuala Trengganu and southery in the opposite direction.

To facilitate the field investigation aerial photographs were used to detail the individual sand ridges. This was found necessary since the imagery could not provide such details which are necessary for location purposes and providing possible access routes through the intervening swamps.

At this juncture only a reconnaissance survey of heavy minerals on the beach ridges along the entire northeastern coastal strip of Peninsular Malaysia has been undertaken (Fig. 8). The results of the 70 beach locations indicated low concentrations of heavy minerals averaging 0.07 percent with a maximum value of 0.59 percent. The tin values from the chemical analysis of the samples are also low. However, in view of the wide spacing of the sample locations, 4 to 6 miles, and the limitation of depth of boring, maximum of 20 feet, there arose a need to conduct a more thorough investigation in the future.

In all the holes sampled there was no marked stratification or seam of heavy minerals except the rare occurrence of minor bands of secondary iron oxides. From a number of samples taken across some prominent ridges it was noticed that there was no definite trend in the variation of the heavy mineral contents.

From the results of this reconnaissance survey it became apparent that much deeper drilling need to be effected, possibly down to bedrock, before any meaningful conclusion can be drawn. The shallow sand material in the ridges is in general lacking in heavy mineral content.

5.0 Significant Results

By far the most useful aspect of this program is the elucidation of large structures along the east coast of the Peninsula. Of particular significance are the circular structures which are believed to be associated with mineralization and whose existence was unknown before.

Geological mapping in this region will in future place more emphasis on the identification of those structures interpreted, especially the northeast trending faults which appear to be concealed structures on the ground.

The so-called impact structure, if the interpretation is correct, represents the most significant result of this program because it is impossible to identify it as such by aerial photographs or ground survey. However, due to the unfavourable conditions on the ground there is as yet no method of checking out this assumption.

The distribution of the "Younger Sediments" along the east coast appears to be more widespread than indicated before. In future this rock unit will have to be carefully identified in the field since it is often difficult to separate from the older unit in some localities.

Along the Pahang coast, on the southern end of Figure 2, small traces of raised beach lines were noted up to 6 miles inland. The existence of these beach lines was unknown before due to their isolation in large tract of coastal swamp.

6.0 Problems

The foremost problem faced by this program is the non availability of good quality, low cloud cover imagery covering the whole Peninsula. In fact only a very small portion of the country could be considered under this investigation because of the above reasons.

In the Trengganu State area no active field work is currently being undertaken. As a result none of the less accessible structural features can be investigated on the ground. This is especially true in the region of the headwaters of the Trengganu River.

The site of the Trengganu River delta related to the hydrogeological investigation is less than ideal for the program envisaged. The delta is far too small in areal extent while the search for groundwater is restricted to locations nearest to existing water supply facilities.

The acquisition of data by the LANDSAT satellite over Peninsular Malaysia is restricted to only one pass. There is no repetitive coverage for comparison purposes. Data when acquired was insufficient to justify any large scale involvement of personnel in the program since they are also involved in other priority projects.

7.0 Data Quality and Delivery

The timeliness of data delivery is good and there is no undue delay in any of the subsequent requests from EROS. The quality and resolution of the imagery is excellent considering the adverse nature of tropical weather in the form of excessive cloud cover.

8.0 Recommendations

With the limited experience drawn from this program the most glaring deficiency is the lack of coverage of the Peninsula. Given the nature of high cloud cover, a large number of repretitive coverage would be needed to offset this handicap. It would be helpful if NASA accord a higher priority to tropical region like Malaysia.

9.0 Conclusion

It was realized in the course of interpretation that the broad synoptic view of the images allowed easy identification of circular features and major fault traces in low-lying areas. Sedimentary units were delineated in accordance with the prevailing rock-types present and where applicable the folding characteristics. Igneous units can easily be differentiated by tone, degree of fracturing, texture and drainage pattern. The large fold structures, anticlinoriums and synclinoriums, of the Younger Sediments on the eastern edge of the Central Belt can also be easily delineated because of the synoptic view which also allows easy definition of interrelations among fold or fault structures.

In future, if LANDSAT imagery is available over an area under investigation, it should be utilised to analyse major structural elements which are normally difficult to determine under tropical weathering conditions.